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Y.F. Khalil

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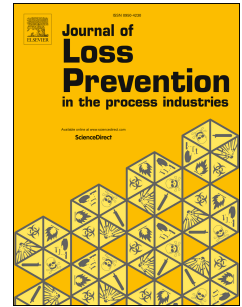
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A probabilistic visual-flowcharting-based model for consequence assessment of fire and explosion events involving leaks of flammable gases

Y. F. Khalil^{*}, Ph.D., Sc.D.

Physical Sciences Department, United Technologies Research Center (UTRC)
411 Silver Lane, East Hartford, CT 06108 USA
khalilyf@utrc.utc.com

Abstract

Leaks of flammable gases from containing systems pose safety concerns in many industrial settings. In this research, state-of-the-art visual flowcharting methodology is employed to develop a probabilistic model to quantify occupational risks of fire and explosion events initiated by leaks that ignite within enclosed spaces. In this model, leak initiation time and leak type (small, medium, or large) are selected based on user-specified probability distribution function and leak probability ranges, respectively. Other inputs to the model include probability distribution of time to failure of mechanical ventilation in the enclosed space, likelihood of presence of an ignition source with energy \geq minimum ignition energy (MIE) of formed flammable gas cloud, probability of leak detection prior to ignition, and conditional probabilities of fires and explosions, given ignition. The model checks whether randomly-selected times of leak initiation and ventilation failure are within user-specified mission time. Number of personnel present near leak source is determined by a user-selected probability distribution. Uncertainties of input probabilities are propagated through the model using Monte Carlo sampling technique. Given occurrence of an undetected gaseous leak in conjunction with presence of an ignition source, ventilation failure, and presence of personnel close to the hazard source, the model calculates frequencies of risks of fire or explosion injuries, averaged over 10^6 Monte Carlo trials per simulation run. Functionality of proposed model is demonstrated by a hydrogen refueling station (HRS) case study in which gaseous hydrogen is postulated to leak from its compressor system. Base case and worst case scenarios as well as sensitivity cases are considered and their simulation results show that, for these postulated scenarios, compressor's small H₂ leaks (unlike medium and large leaks) pose intolerable occupational risk frequencies that exceed the acceptable risk level of $1.0E-4$ /year as well as NFPA's selected risk guideline of $2.0E-5$ /year which is driven by the comparative risk to gasoline stations. To mitigate predicted occupational risks to acceptable levels, safety control measures and best practices are recommended. The proposed model can be used as a training tool for first responders to fire and explosion events initiated by leaks of flammable gases. The model allows user-specified 'what-if' scenarios with or without risk mitigation measures. In addition to HRS, the model can be applied to a broad range of industrial applications such as natural gas refueling stations, indoor chiller systems which employ flammable refrigerants, and warehouses equipped with hydrogen-powered forklifts. Risk insights from this model's simulations can also support safety codes & standards and root cause investigations of industrial fire and explosion events.

Key words: consequence analysis, refueling stations, first responders, flammable gases, gaseous leaks

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